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Operational considerations and data science needs for a large heterogeneous network

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With credit to IIT Space Weather Lab students and conversations with colleagues.

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SWON focus areas

- Geomagnetically induced currents
- Thermospheric expansion
- Ionospheric disturbances
- The aurora

- For the operational system to be successful, specific objectives should be identified for each area.

Example: Distributed sensing

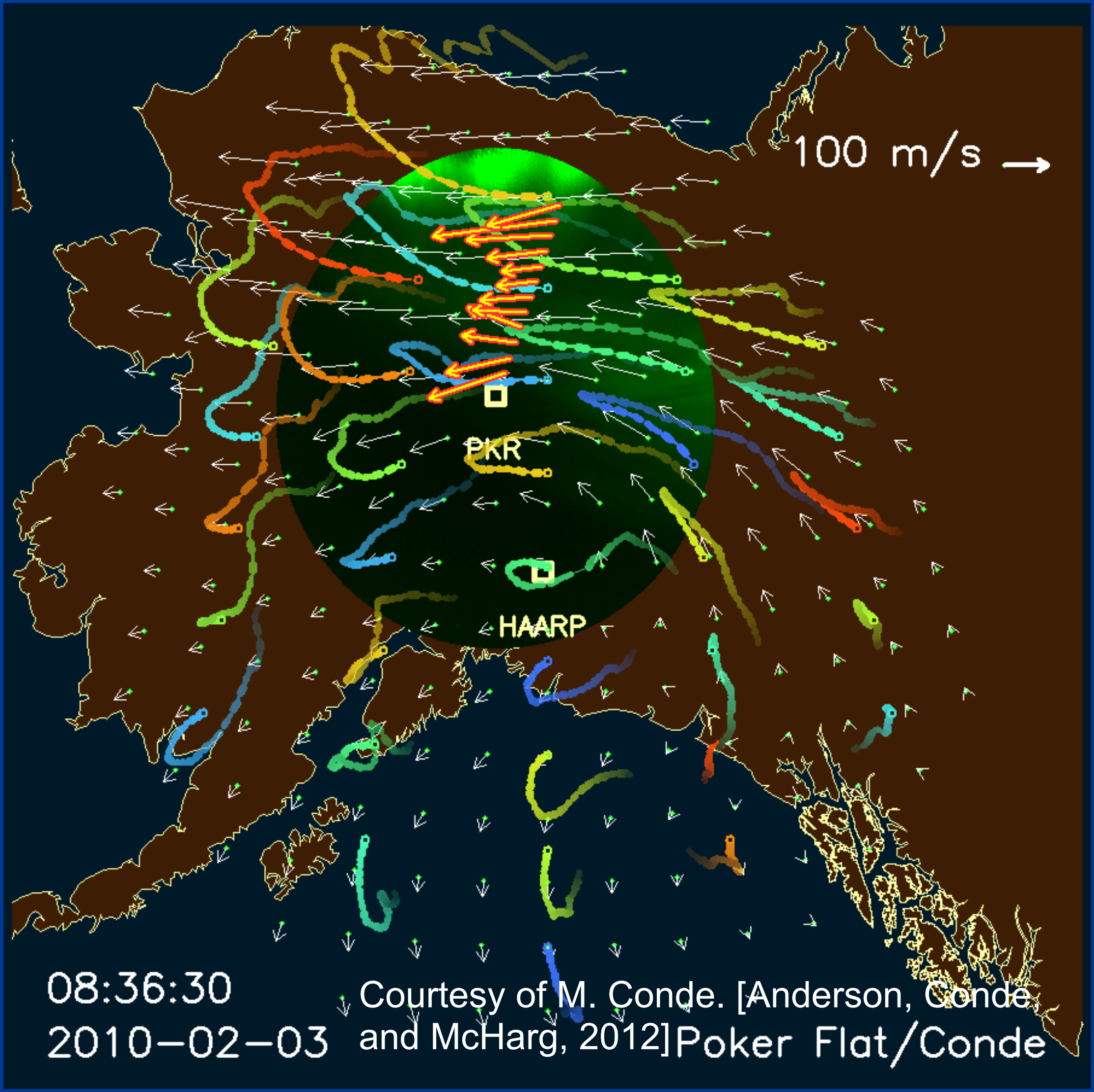
e.g., Objective: to enable auroral forecasts

What is the service?

- Provision of data
- What latency, what rate, synchronization, what levels data products, what scale sizes?
- Real-time science required?

Who are the users?

- Modelers, data assimilators, instrument developers? The public?



Courtesy of M. Conde. [Anderson, Conde, and McHarg, 2012]

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Example: Sunburst system

- e.g., provide evidence of GICs
- EPRI project measuring GIC events in actual systems
- http://sunburstproject.net/index.html

EPRI SUNBURST Project

Project News

The new EPRI SUNBURST Project website is beginning to come alive. This page and this website will be undergoing frequent significant changes as we progress with development of each feature.

Links for the various tools are on the right. The only tools currently active are the historical data tool and the latest GIC readings. When you click on those links, you will be asked to enter your user id and password.

SUNBURST Tools

- Monitoring Map
- Real-time Data
- Storm Catalog
- Active Alerts
- Historical Data
- Latest GIC Readings

About The Project

The EPRI SUNBURST Project is a collaborative project for monitoring of geomagnetically-induced currents (GIC's) and their impact on the power grid.

Metrics

- Metrics for successful operation of each objective should be defined.
- Requirements would then follow, for each metric.
- The metrics may actually be competing and require tradeoffs in system design.
  - E.g., availability, network resolution vs coverage, latency, rate

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Example

- Federal Aviation Administration's Wide Area Augmentation System (WAAS)
  - Distributed homogeneous array for ionospheric monitoring with master control stations processing for near real-time broadcast
- Objective: to provide precision approach service for civilian aircraft using GPS
  - Primary guidance down to 200 ft height for Category I service.
- Metrics: accuracy, integrity, availability, continuity
  - Formally defined probabilistically, e.g., probability of hazardously misleading information 10^-7 per approach
  - Risk trees, prior probabilities of faults

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Requirements

- Heterogeneous network: system of subsystems approach
  - Define requirements for each at network level, and if needed, at individual unit level.
- Performance-based requirements vs. instrument-specific requirements
  - Trades off generality and modularity of network for ease of quantification
- Life cycle
  - OSSEs
  - Test-bed
  - Full system in phases
  - Upgrades
  - Winding down/obsolescence
- Data training sets, validation sets.

Standardization and attention to user interface

- Lowers the barriers to research entry
- Example: Global Navigation Satellite System (GNSS) networks, e.g., International GNSS Service
  - Single repository with map and standardized recording of site history gives ease of use.
  - User-contributed
  - Nothing draws a crowd like a crowd!
  - Receiver INdependent EXchange (RINEX) format
    - Text file header specifies which observables are provided
    - One RINEX script covers 1000s of receivers!

Example: UNAVCO

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UNAVCO

Community | Projects | Instrumentation | Data | Software | Science | Education

UNAVCO, A NON-PROFIT UNIVERSITY-GOVERNED CONSORTIUM, FACILITATES GEOSCIENCE RESEARCH AND EDUCATION USING GEODESY.

Index

- Help with Projects
- Project Support & Services
- Major Projects
- Other Projects
- Past Projects

Projects

UNAVCO provides project support to principal investigators (PIs) engaged in research funded by our core sponsors including the National Science Foundation Earth Sciences (NSF-EAR), NSF Office of Polar Programs (NSF-OPP), and the National Aeronautics and Space Administration's Solid Earth and Natural Hazards (NASA-SENH) Program. Other non-core sponsors and agencies are supported on a full cost recovery basis. Some major projects in which UNAVCO is involved currently include the **Plate Boundary Observatory**, **NASA Geosciences**, **COCONet**, **TLALOCNet**, and **POLENET**.

Help with Projects

Do you need help with any of the project planning topics listed here?

Request Support for:

Project Technical Planning of PI projects involving GPS/GNSS; borehole instrumentation including strainmeters, accelerometers, and seismometers; terrestrial laser scanning (TLS); communication and power systems.

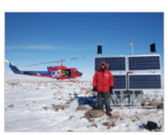
Project Budgeting includes project design and implementation costs, including possible equipment design and/or equipment loan, and is co-developed with the PIs.

Broader Impacts Proposal Guidance *submitted by community PIs* — UNAVCO can provide guidance to PIs with proposal planning and budgeting for broader impacts.

Letters of Support can be provided by UNAVCO to detail the resources and support that UNAVCO will provide should the proposal succeed.

Email **projects@unavco.org** for quick questions or if you cannot find what you need in the project topics covered below.

See more Help with Projects »



Project Support & Services

UNAVCO provides comprehensive project technical support services to investigators using GPS/GNSS, TLS, UAS, and SAR data. These services range from loaned equipment, testing, configuration, integration, and new equipment designs for field deployments to technical training for campaign field deployments and permanent station installations.

Geophysical Event Response helps coordinate community field activities, hardware, and data requests following an earthquake, volcanic eruptions, or other notable geophysical

GPS/GNSS Support provides PI support for projects using GPS or full GNSS:

- **Permanent Station Support**
- **Campaign & Kinematic Support**
- **GNSS Modernization**

Terrestrial Laser Scanning (TLS) Support with instruments, associated digital photography GNSS and ancillary equipment, as well as trained field engineering staff, software licenses, and TLS data archive.

Unmanned Aerial Systems (UAS) Support

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Data science needs

- User-based requirements, e.g., data assimilators may want to provide
  - Forecasting with uncertainty quantification
  - Actionable forecasts for space weather
- How much overlap between understanding (modeling) and prediction (data assimilation) is required?
  - No number of measurements or observations would give all possible states/parameters
  - Deterministic vs probabilistic approaches

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Error modeling

- One challenge of applied data-driven methods for the MIT system is error characterization both of measurements and underlying models

- Why needed?
  - Measurement error models are needed for accuracy and integrity (“trustability”).
  - Model uncertainties – a broader problem for all fields
  - Significantly influence results of data assimilation when using optimized methods.

Example: Assimilation of Ne, for Φ and u

Data science

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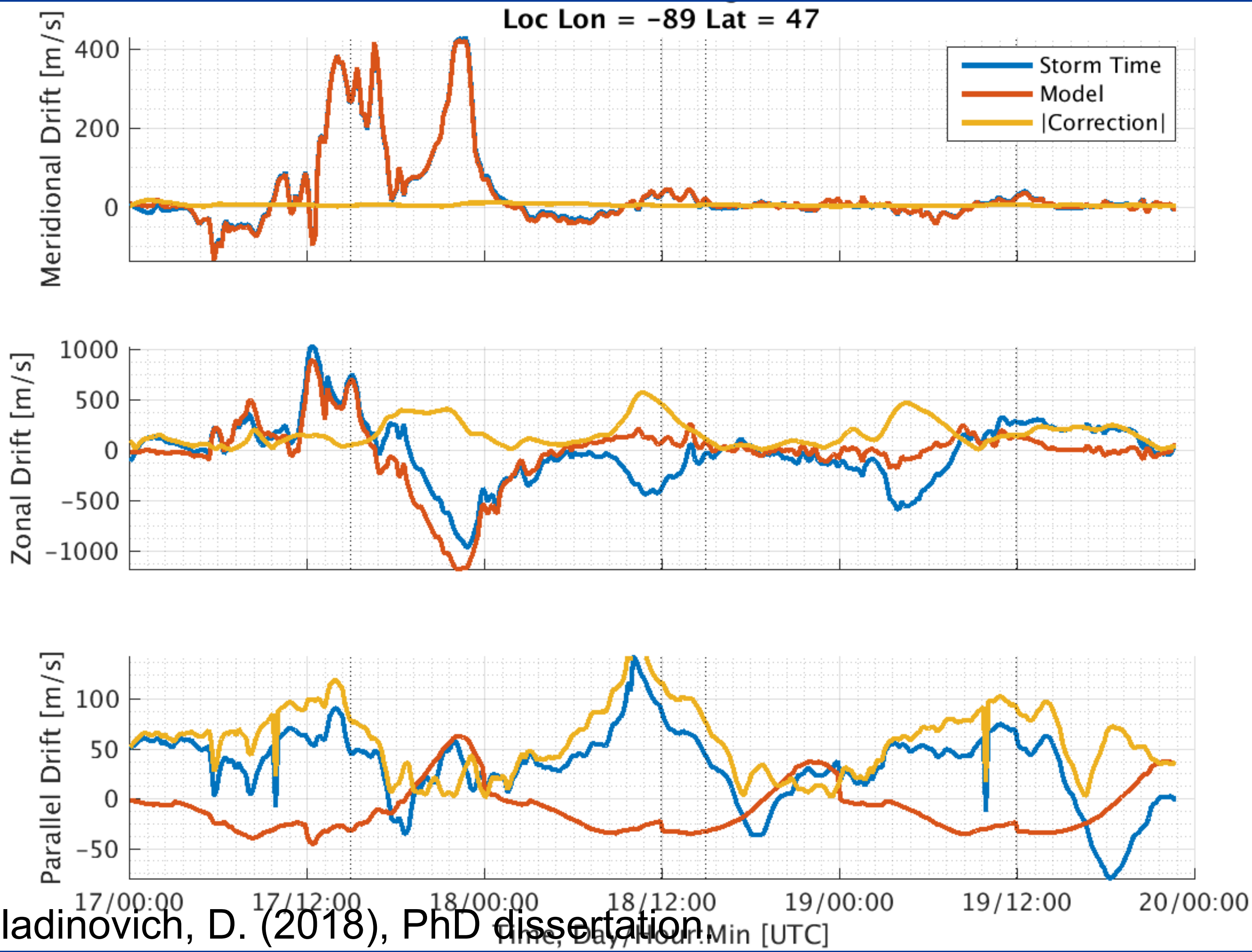

Miladinovich, D. (2018), PhD dissertation.

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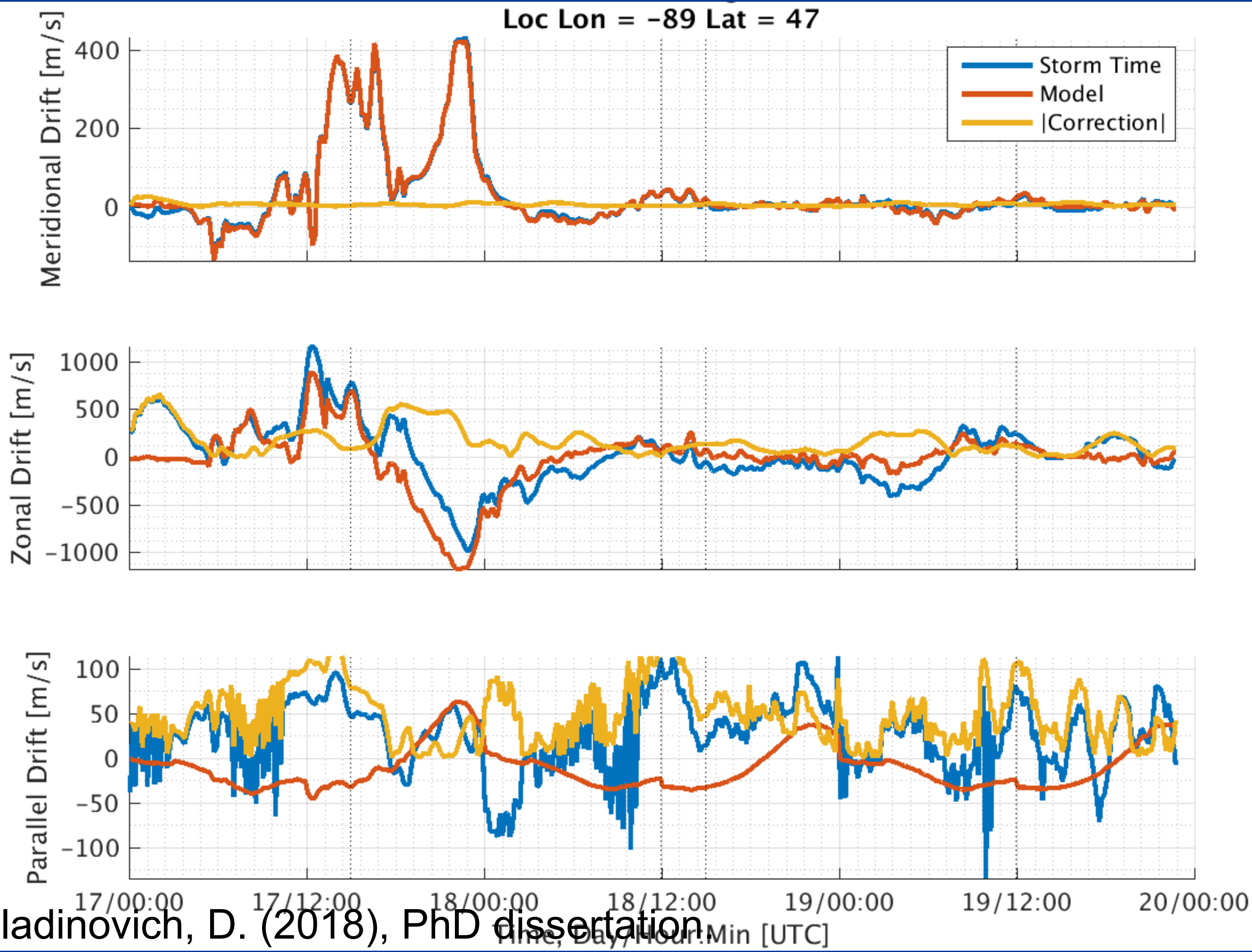
Assimilation of Ne and u, for Φ and u



Miladinovich, D. (2018), PhD dissertation.

Summary of areas of thought/ discussion

- Operational considerations
  - Objectives – understanding vs prediction not identical
  - User need-based metrics and requirements
  - Life cycle from test-bed to phases, to upgrades, to winding down?
  - Services to enable user productivity
- Data science needs
  - Measurement error models
  - As users, algorithm developers of filtering/learning methods need process and measurement noise characterization